

# **METHOD AND APPARATUS FOR TRANSMITTING/RECEIVING HIGH ORDER DIGITAL SIGNALS OVER TWO RF CARRIERS IN A RADIO REGENERATION SECTION**

## **BACKGROUND OF THE INVENTION**

### **1. Field Of The Invention**

The present invention relates to radio transmissions and in particular it concerns a method and apparatus for transmitting/receiving STM-4 (SDH) or STS-12 (SONET) digital signals over two RF carriers in a respective SDH or SONET radio regenerator section.

### **2. Description Of The Prior Art**

In present telecommunication systems, the need often arises (particularly with operators who have to manage congested networks) of providing high capacity radio systems with high spectrum efficiency and not much complex architecture. These radio systems are required to transmit high order digital signals, such as STM-4 (SDH) or STS-12 (SONET) synchronous hierarchy levels, at 622.08 Mb/s. Such links must be capable of being inserted in optical networks on STM-4 interface nodes with all the features of performance monitoring, management, protection, etc... The above needs are also apparent from the last issues of some ETSI Recommendations.

The solution which is at present known for interconnecting an STM-4 data stream with a radio equipment provides for the transmission of four STM-1 signals over four corresponding RF carriers. In essence, it is a solution providing for the transmission of four STM-1 signals in the radio section and allows the transport of an STM-4 stream in a regenerator section, by using four RF carriers in a 4+2 protection system configuration.

It is clear that this type of approach does not optimize the spectral efficiency of the transmission system. Moreover, it requires the use, in the radio link, of four transceivers (in addition to two spare transceivers) and the management of four STM-1 channels in a minimal configuration of the protection system that contemplates the use of two protection channels (4+2 protection).

## **SUMMARY OF THE INVENTION**



A further object of the present invention is providing an apparatus for receiving high order synchronous digital signals transmitted via radio, wherein said apparatus comprises: means for combining the sub-frames, said means interleaving by columns the received sub-frames through a mapping process based on the recognition of the respective alignment words and of the header to identify the correct sequence of the two received sub-frames; and wherein said apparatus further comprises means for extracting the RSOH bytes from a frame complementary section; and means for inserting the RSOH bytes in the respective positions after the step of recomposition-by-columns.

Further advantageous characteristics of the methods and apparatuses are set forth in the respective dependent claims. All the claims are considered as an integral part of the present description.

As far as the transmission of SDH synchronous signals is concerned, the basic idea of the present invention is to transmit an STM-4 (or possibly a STS-12) signal (with a line optical interface, in accordance with the ITU-T Recommendation G.957) in a radio equipment by using only two RF carriers, without performing any signal multiplexing or demultiplexing, and without any pointer processing, thus using the radio system as a pure regenerator network element (NE).

In this concern, just for the sake of clarity and in order to avoid a too long description, the following description is mainly referred to SDH (Synchronous Digital Hierarchy) transmission but it is well considered that it is equally extended and applicable to SONET (Synchronous Optical Network) transmission.

The present invention will certainly result in being clear from the following detailed description, given by way of a mere non limiting example, to be read with reference to the attached drawing figures.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

In the drawings:

- Fig. 1 shows a block diagram of the transmitter apparatus according to the present invention;
- Fig. 2 shows a block diagram of the receiver apparatus according to the present invention;
- Fig. 3 schematically shows how the de-interleaving process occurs;

- Fig. 4 shows the AUOH pointers of an STM-4 signal before and after the subdivision of the signal itself into two sub-frames;
- Fig. 5 shows the header of an STM-4 frame;
- Fig. 6 shows the four bytes of the alignment word that are generally used by a state machine to detect the alignment condition;
- Fig. 7 shows the alignment strategy used for an STM-4 frame;
- Fig. 8 shows, in two STM-4/2 sub-frames, the bytes that are used as headers to identify their arrival order at the receiver side;
- Fig. 9 shows the alignment device of the STM-4/2 sub-frames; and
- Fig. 10 shows the finite state diagram of the alignment strategy used for the STM-4 frame and for the STM-4/2 sub-frames.

### **BEST MODE FOR CARRYING OUT THE INVENTION**

As said above, in order to transmit high order digital signals from one radio equipment to another radio equipment in a transmission system, the present invention substantially provides for subdividing, in a manner that will be described later on, the frames of the signals to be transmitted into two sub-frames. These two sub-frames are then transmitted by using only two RF carriers, without performing any signal multiplexing or demultiplexing operation, and without any pointer processing, thus using the radio system as a pure regenerator network element (NE).

The method of the invention, hereafter described for the transmission of STM-4 SDH signals, consists in dividing the STM-4 signal which is present at the network interface (namely, at the input of the transceiver) into two STM-4/2 signals to be transmitted over two modulated carriers in proper channel spacing and with a minimal configuration (2+1) of the protection system. Clearly, "channel spacing" means the distance between two adjacent frequencies in the channeling used.

For example, in a bandwidth of about 55 MHz and by using two cross-polar carriers at the same frequency with a Cross-Polar Interference Canceller (XPIC) it is possible to transmit an STM-4 signal, thus increasing the spectrum efficiency of the system up to  $622.08 \text{ Mbps}/55\text{MHz} = 11.31 \text{ bit/s/Hz}$ . It is to be noticed that the transmission of the two STM-4/2 signals is independent of the radio frequency used and of the modulation scheme applied. Accordingly, it is possible to implement the considerations that will be described below both in the short-haul systems and in the long-haul ones.



In consideration of the above, the transmitter apparatus (TX) according to the present invention will now be described with reference to Fig. 1. On the incoming STM-4 signal, the Regenerator Section Termination (RST) performs the regeneration of the RSOH (Regenerator Section OverHead) bytes and calculates the parity byte B1 of the STM-4 frame. In other words, at the RST section, the DCCR, E1, F1 bytes (and possibly other service channels) are terminated by, extracted from, the STM-4 frame and passed on in the RFCOH section so as to maintain at all times the interconnection of the supervision network between the line side and the radio side. The RFCOH (Radio Frame Complementary OverHead) section increases the capacity of each sub-frame and allows the transmission of the DCCR, E1, F1 channels and other service channels protected in an at least 1+1 configuration. In essence, the bytes containing the service channels are interleaved with the columns of the STM-4/2 sub-frames and transmitted over two radio channels (for instance, a working channel (WOCH) and the protection one (PRCH) or over the two working channels (WOCH) in case there are not noise and/or decay phenomena in each of the sub-frames transported on the working channels). The 1+1 protection configuration assures the preservation of the network interconnection also in the event of loss of one of the two sub-frames in the radio channel. Thus, in principle, it might happen to lose the information to be transmitted but it becomes more difficult to lose the interconnection of the supervisory network.

As shown in Fig. 3, the de-interleaving process divides the incoming STM-4 standard frame, by partitioning it by columns over two STM-4/2 streams at 311.04 Mb/s. In other words, the bytes of the odd columns are arranged in the first sub-frame (sub-frame N.1) whereas the bytes of the even columns are arranged in the second sub-frame (sub-frame N.2). Naturally, in so doing, the pointers of the single sub-frames will no longer be valid. As still shown in Fig. 1, the block (DE-INT) that carries out the frame de-interleaving process, also receives information concerning synchronization from a clock recovery block (CKR). Hence, the two STM-4/2 sub-frames will be synchronous with the STM-4 standard frame.

Provided downstream of the block (DE-INT) carrying out the frame de-interleaving, is a multichannel switch (SW) able to operate the hitless protection on the two sub-sets into which the original frame is divided in order to reduce the probability of information loss should problems on the radio channel occur. Therefore, the automatic exchange apparatus operates on the two STM-4/2 signals in a 2+1 protection configuration.



described de-interleaving process applied to the STM-4 frame, automatically place themselves in the columns  $X[i]$  (where  $i=1, 7, 13$ ) of the first sub-frame.

The overhead of an STM-4 frame is represented in Fig. 5 where “x” denotes the bytes reserved for national use, “\*” denotes the unscrambled bytes that must be handled with special care, and “Δ” denotes the bytes dependent on the transmission medium. In an STM-4 frame the alignment word is composed of 24 bytes (12xA1 and 12xA2), but the state machine that detects the alignment condition, as it is known, works only on the four central bytes, namely A1, A1, A2, A2 (see Fig. 6).

The alignment strategy used for an STM-4 frame considers a “short word” (from the alignment state to the OOF (Out Of Frame) condition) and a “long word” (from the OOF condition to the alignment state), as shown by way of example in the table of Fig. 7.

In an implementation of the device according to the present invention, the parameters that characterize the performance of the STM-4 aligning device, whose finite state diagram is illustrated in Fig. 10, are summarized in the following table:

parameters	
Average recovery T (ms)	0.259213
Max recovery T (ms)	0.393239
Forced loss T (s)	522581
Min. forced loss T (s)	508
Alignment loss average frame N	5
Alignment loss average frame N variance	0.116
Probability of false alignment loss	$2.7 \times 10^{-10}$

When the de-interleaving process on the transmission side divides the frames by columns into two different sub-frames, the same alignment word is generated for each of the two sub-frames. Hence the algorithms used in the alignment devices for the STM-4 and STM-4/2 frames are the same since they operate on the bytes A1 A1 A2 A2 of the sole central portion of the entire alignment word (bytes # 1.11, #1.12, #1.13 and #1.14 for the STM-4 standard frame and bytes #1.5, #1.6, #1.7 and #1.8 for the STM-4/2 frames). Moreover, it is necessary to univocally identify the correct sequence of the two subsets extracted from the STM-4 frames. To this end, the four A2 bytes (#1.9, #1.10, #1.11, #1.12) of the alignment word directly adjacent to the area in which the alignment device operates that will be used as a sort of “header” for the two sub-frames, are “colored”. For instance (see also Fig. 8):

A2 A2 A2 A2 = 00001111 00001111 00001111 00001111 = 0F 0F 0F 0F



for the sub-frame N.1

A2 A2 A2 A2 = 01010101 01010101 01010101 01010101 = 55 55 55 55

for the sub-frame N.2

Thus, during the process of reconstructing the original STM-4 signal at the reception side (RX), the interleaving algorithm is able to identify the correct sequence of the two sub-frames transmitted in the radio channel by reading the configuration of the header bytes A2 after the alignment. Finally, the complete standard alignment word (24 bytes) is rewritten in the reconstructed STM-4 frame.

Using the solution described above, there is no need to synchronize the signals in the functional blocks described. In fact, at the transmission side (TX), the clock used for the de-interleaving mechanism and for generating the two STM-4/2 sub-frames is derived directly from the STM-4 standard signal coming into the system. At the reception side (RX), the clock used in the reconstruction process (interleaving) of the STM-4 frame can be directly selected from at least one of the STM-4/2 signals transmitted in the radio section synchronous with the incoming STM-4 signal. The failure indications on the clock extractor (LOS CK) will indicate the need to use the clock of the other STM-4/2 signal.

In the section for the reconstruction of the STM-4 frame (at reception side), it is necessary to carry out an alignment procedure of the two STM-4/2 streams transmitted in the radio section, as for instance shown in Fig. 9. It is necessary to compensate the possible clock shifts due to propagation phenomena induced on the radio transmission channel and to differences of electrical paths (length of the feeders, etc...). The alignment system provides for the use of a pair of elastic memories and a 311.04 MHz PLL connected to the clock selection block.

It can be assumed that propagation phenomena (fading) may cause a clock shift equal to about one half symbol period corresponding to  $\pm 4$  bits. In fact, by using a 128-state modulation scheme, the length of the transmitted symbol is equal to 7 bits, as results from the following considerations:

□ Modulation scheme	128 QAM
□ Bit rate (without redundancy)	311.04 Mb/s
□ Bit period	$T_b = 3.2 \text{ ns}$
□ Number of bits per constellation symbol	7 bits
□ Symbol period	$T_s = T_b \times 7 \text{ bits} = 22.4 \text{ ns}$
□ Delay due to fading	$\pm T_s/2 = \pm 11.2 \text{ ns}$
□ Delay due to fading (in bits)	$\pm 11.2 \text{ ns}/T_b = \pm 3.5 \text{ bits}$

